Measurement and Verification Retro-Commissioning of Commercial Buildings

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Learning Objectives
Measurement and Verification during Retro-Commissioning of Commercial Buildings

- Understand the Steps of Retro-Commissioning of a Commercial Building
- Understand typical processes of Retro-Commissioning; to improve energy and water efficiency, to identify, recommend, and implement energy conservation measures, and to provide documentation and training to property management personnel
- Understand four step process of Retro-Commissioning that includes the Planning phase, Investigative phase and development of a Master List of Findings, Implementation phase, and Verification phase
- Understand the importance steps of Measurement and Verification during the Implementation phase during Retro-Commissioning

The Steps of Retro-Commissioning

- Typically applied to existing buildings that are inefficient and/or have performance problems
- Develops a process to plan, investigate, implement, and verify energy and water efficiency and operational improvements identified from a Master List of Findings
- Retro-Commissioning is a four-step process that includes:
  - Planning phase with written RCx plan and assessment;
  - Investigative phase with analysis of energy and water efficiency and bench-marking and development of a Master List of findings;
  - Implementation phase of the prioritized energy efficiency and operational improvements;
  - Measurement and Verification phase of capital improvements in energy and water efficiency
- May address latent design or construction deficiencies
- Goal of achieving energy and water efficient and well-operated buildings
- Provides documentation and operator training

Goals of Retro-Commissioning

- Achieve energy and water efficiencies with peer buildings
- Deliver efficient and well operated buildings
- Improve occupant comfort and enhance indoor air quality
- Resolve existing operational problems and systems deficiencies
- Identify and enhance building system documentation
- Identify and enhance training needs of operation and maintenance staff
- Measure and Verify results of improvements made during implementation of energy and water conservation measures

Importance of Retro-Commissioning

- Takes a holistic view of existing buildings by observing, monitoring, trending, and improving energy and water efficiencies and performance of those systems
- Goes beyond day-to-day building maintenance and resolving short-term problems
- Thorough assessment/investigation of typical mechanical HVAC systems, lighting, automatic controls, energy management systems, and water-consuming systems
  - Obsolescence of energy and water-consuming systems may necessitate planning for capital investment in upgrades
  - Operational and occupancy changes may require reconfiguration of the mechanical HVAC and lighting systems and controls
  - Helps Owner identify and meet targeted energy and water efficiency and performance requirements through benchmarking
- Reduces potential for unexpected repairs and replacements
- Verifies that maintenance personnel are adequately trained and have documentation
- Identifies and addresses potential HVAC operational concerns such as indoor air quality and building pressurization

Retro-Commissioning Process

- Planning phase
  - Screening, assessment, and developing a utility use profile
  - Reviewing building operation, obtaining energy and water billings, development of Retro-Commissioning plan
- Investigative phase
  - Survey energy and water-consuming equipment and control sequences
  - Analyze utility records
  - Conduct performance testing
  - Conduct energy audit
  - Develop Master List of Findings

Retro-Commissioning Process

- Implementation phase
  - Select energy and water efficiency and operational improvements from Master List of Findings with consideration of Owner's budgets
  - Conduct investment grade ASHRAE Level II Energy Audit if needed
  - Utilize mechanical and electrical contractors to implement capital improvements
- Measurement and Verification phase
  - Development of Re-Commissioning plan
  - Perform functional testing, remote monitoring, energy and water use trending
  - Develop Systems Manual
  - Coordination of operator training

Retro-Commissioning Process

Investigation Phase

- Obtain and analyze available documentation such as drawings, automatic control sequences of operation, and energy management system settings
- Perform diagnostic monitoring of operating characteristics such as utility meters, temperature and relative humidity levels, building pressurization, and operating hours
- Review and analyze energy and water usage billings and perform benchmarking against peer buildings using databases such as CBCES and/or Energy Star Portfolio Manager
- Perform functional and diagnostic tests using equipment and recorders
- Conduct energy and testing analysis. Model to identify potential energy conservation measures (ECMs)
- Perform simple, low-cost maintenance and repairs during investigation and testing
- Develop Master List of Findings as a decision making tool for the Owner. Incorporate ECMs and estimated rates of return.
- Prioritize and select energy and water saving and operational improvements using low through high cost versus benefit analysis

Retro-Commissioning Process

Implementation Phase

- Implementation Plan from Master List of Findings and Owner's available budget
- Conduct investment grade energy audit, if required, of proposed ECMs and estimated rates of return for Owner's decision making of implementing proposed ECMs
- Operational improvements using Owner led/in-house staff for simple, low-cost improvements and outside MEP contractors for capital intensive improvements
- Develop scope of work for mechanical and electrical contractors from Master List of Findings and Owner's decisions on capital improvements
- Engage mechanical and electrical contractors to implement capital improvements from Master List of Findings
- Test improvements for anticipated results
- Update Master List of Findings with results and schedules for further improvements
- Determine the options for Measurements and Verification (M & V) consistent with the facility's goals and develop the plan as needed

Retro-Commissioning Process

Measurement and Verification Phase

- Install monitoring equipment such as utility meters, temperature and relative humidity recorders, and perform trending using energy management system
- Document RCx activities and ECMs implemented
- Include updated Master List of Findings, updated estimates of cost savings, results of monitoring of improvements, test results, recommended frequency of re-commissioning, complete documentation, and list of further capital improvements warranting investigation in final report
- Compile Systems Manual including Owner's operating requirements, updated sequences of operation, and operation and maintenance manuals
- Develop Re-Commissioning Plan to keep systems at peak performance
- Provide training for in-house staff
- Hold a close-out/hand off meeting

Summary of the Retro-Commissioning Process

Planning Phase
Survey, Analyze, Energy & Water Use Profile
Document current facility requirements
Retro-Commissioning Plan

Investigation Phase
Diagnostic Testing and Monitoring
Master List of Findings
List of Improvements for Implementation

Implementation Phase
Implementation Plan
Investment Grade Energy Audit
Implementation of ECMs

Measurement and Verification Phase
Diagnostic Measurement and Verification
Systems Manual
Recommissioning Plan
Training of In-house Staff

RCx Case History
Travis County Medical Examiners Office

- Travis County requested RCx at the Medical Examiners Office due to reported HVAC ongoing performance problems and migration of odors from the Morgue and Autopsy rooms on the first floor to adjacent occupied spaces and the second floor.
- Approx. 5-years old and 60,000-square feet.
- Terracon performed extensive investigation and testing of the HVAC systems:
  - Identified differential air pressures between the Morgue and Autopsy rooms and adjacent spaces,
  - Reviewed BAS systems to trend data, observed numerous openings in demising walls and floors allowing migration of odors, and
  - Found problems with automatic controls settings, calibration, and reliability.

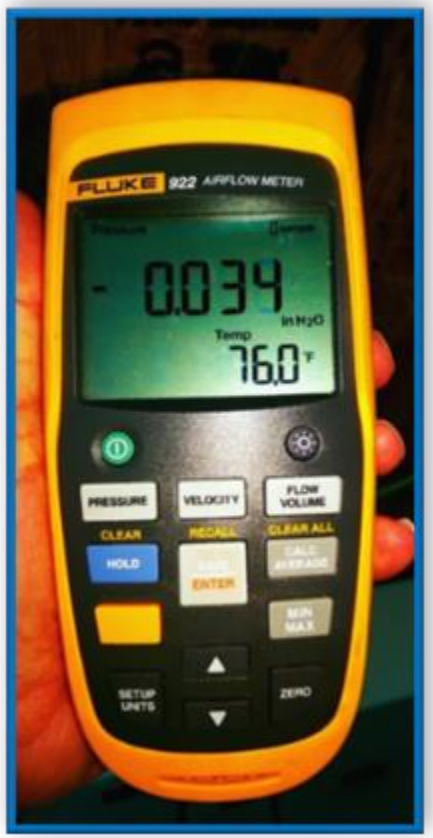
RCx Case History
Travis County Medical Examiners Office

- Investigation:
  - Utilized utility records.
  - Performed functional performance testing, conducted air and water balancing.
  - Performed energy management system trending and diagnostics.
  - Conducted visual assessments to complete a plan for implementation.
  - Developed Master List of Findings for decision-making.
- Implementation included development of a plan and associated scope of work for mechanical contractors for capital intensive improvements.
- Monitoring and Verification conducted at the conclusion of Implementation that reviewed and evaluated the plan based on actual improvements.

- Used functional testing, automatic mechanical controls monitoring, and trending using energy management software to trace implemented improvements in building operation.

Diagnostics Performed in Investigative Phase

- Measured and recorded building indoor air pressures, floor to floor differential pressures, and corridors to Morgue and Autopsy rooms using digital manometer.



Diagnostics Performed in Investigative Phase

- Digital flow hoods were used to determine supply and return CFM rates at air grilles versus design
- Digital flow hoods were also to determine exhaust CFM rates at air grilles and exhaust hoods versus design

Diagnostics Performed in Investigative Phase

- Obtained temperature and relative humidity measurements at varying periods of a 24-hour day
- Placed temperature and relative humidity recorders in strategic places for 5-day continuous recordings and graphing

Diagnostics Performed in Investigative Phase

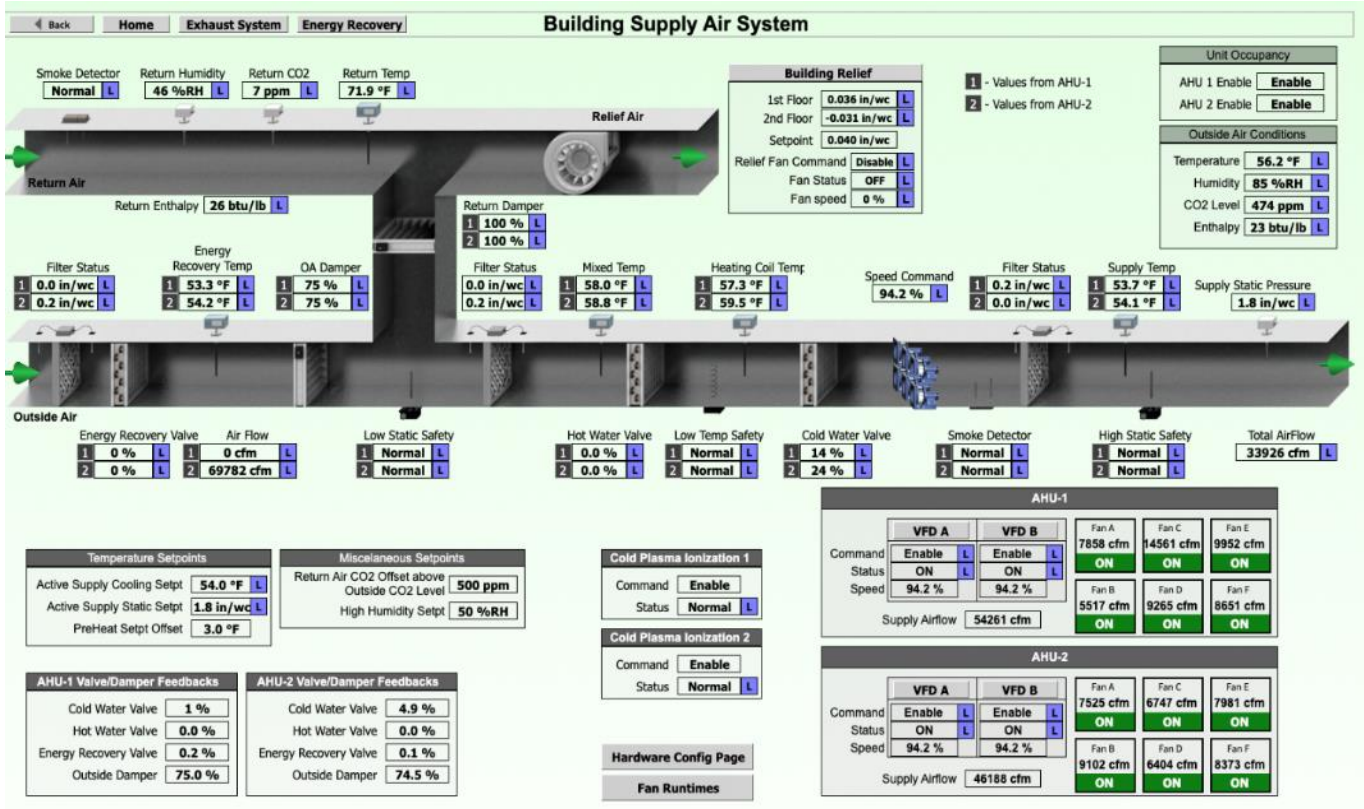
- Conducted observations of air tightness of operation at sliding door vestibules during typical 24-hour days

Diagnostics Performed in Investigative Phase

- Conducted observations of integrity of floor, wall, transfer ducts, and air grille sealants

Diagnostics Performed in Investigative Phase

- Building automation system was used to track and trend HVAC system



Diagnostics and Measurements Conducted

- Conducted in depth HVAC System Observations and Diagnostics
  - Anemometer testing of primary air handler CFM versus design, rate of change in CFM and average CFM
  - Digital manometer to record supply air duct static pressure changes
  - Digital duct pressure testing of air leakage rates of ductwork
  - Digital temperature measurement of primary air handler supply air temperature versus design, chilled water supply and temperature rise versus design, chilled water setpoint versus rate of change and average chilled water circuit temperatures
  - Observed VAV box damper controls and response times
  - Checked calibration of VAV box room thermostats
  - Observed return air box damper controls and response times

Implementation Phase Activities

- Applied sealants at floor-to-floor openings, duct penetrations, corridor/morgue wall openings and designated negative pressure areas
- Air balancing of primary air handlers and exhaust fans to design conditions and maintain negative air pressure on lower floor, laboratories, and morgue
- Calibrated room thermostats VAV box dampers to design air flows
- Added chilled water storage to system to lessen rates of change during water chiller internal cycling
- Replaced and calibrated of chilled water control valves at primary air handlers and VAV heating hot water valves

Verification Phase Activities

- Digital manometers and differential pressures sensors in building automation system (BAS) to check effectiveness of sealants at floor to floor openings and duct penetrations
- Digital manometers and differential pressures sensors in BAS to measure effectiveness applying sealants at corridor to morgue wall openings in corridors and in designated negative pressure areas
- Conducted site visits during low and high usage periods of the building to detect odor migration to upper floors
- Added 500-gallon chilled water storage to system to lessen rates of change in system chilled water temperatures during water chiller internal cycling

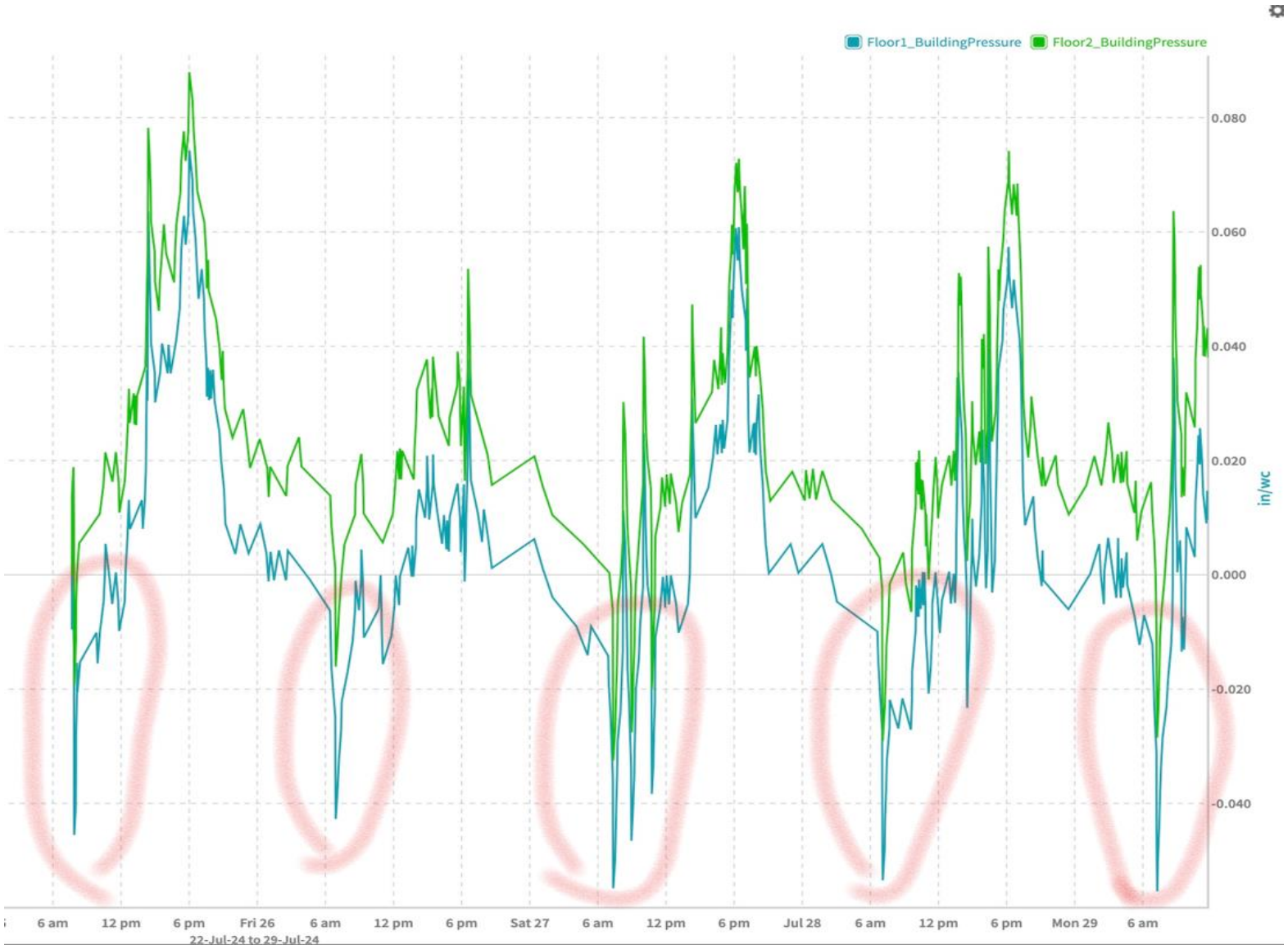
Verification Phase Activities

- BAS used to verify and trend air balance of primary air handlers and exhaust fans after achieving design conditions
- BAS used to verify and trend negative air pressures on lower floor, laboratories, and morgue with respect to corridors and second floor
- BAS used to verify and trend room thermostats
- BAS used to verify VAV box damper positions after air flows were calibrated to design
- BAS used to verify and trend water chiller temperature and rates of change in temperatures
- BAS used to verify calibration of chilled water control valves at primary air handlers and VAV heating hot water valves

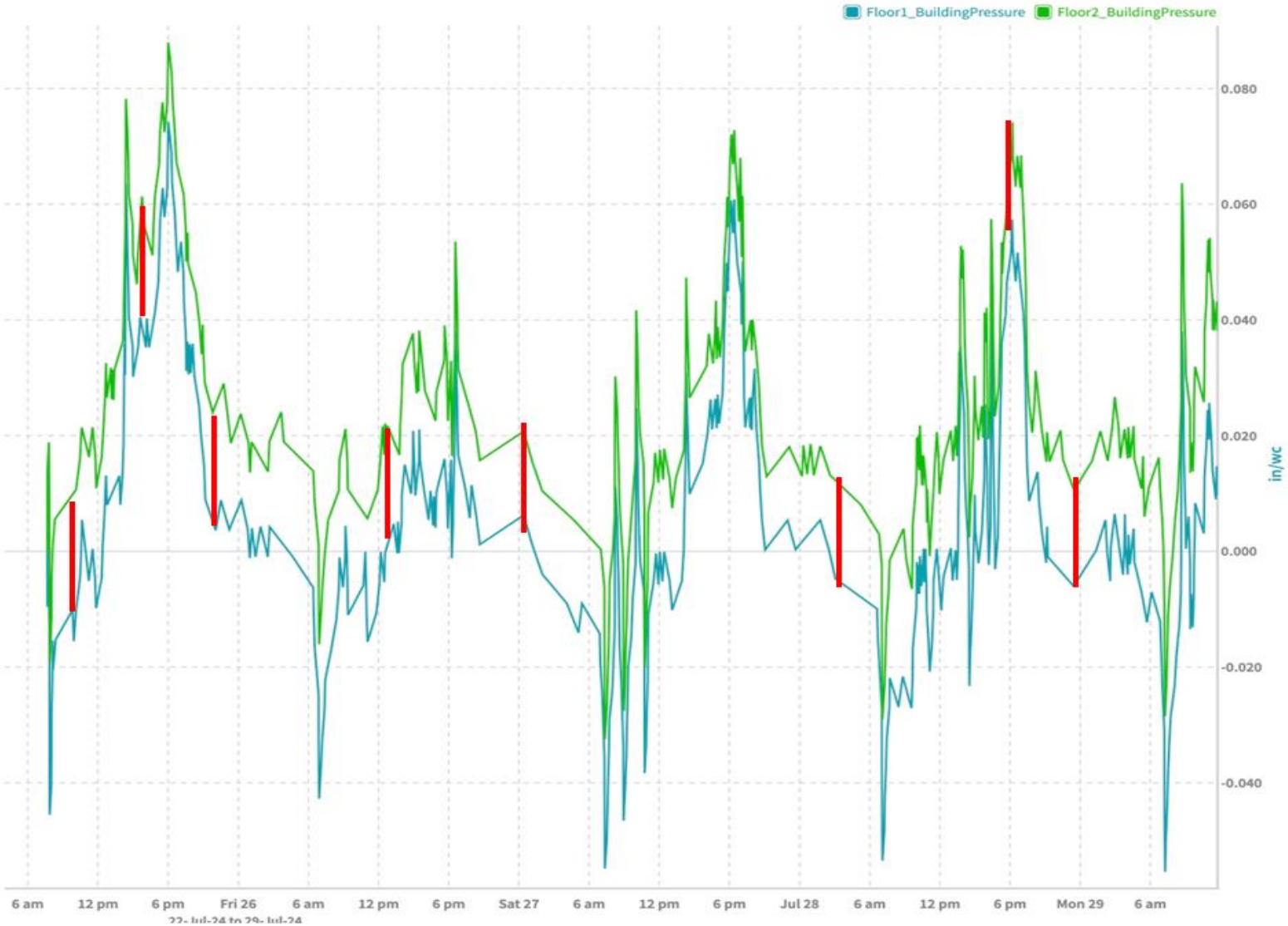
Findings, Resolutions, Verification

Issue	Findings	Resolution
Openings found between morgue and adjacent spaces not well sealed, allowing odor migration due to differential pressures	Numerous pipe, duct, conduit floor to floor penetrations not sealed Duct leakage observed in exhaust, return, and supply duct was repaired	Pressure induced smoke test performed to identify leaks in enclosure and ducts Structural and ductwork openings sealed

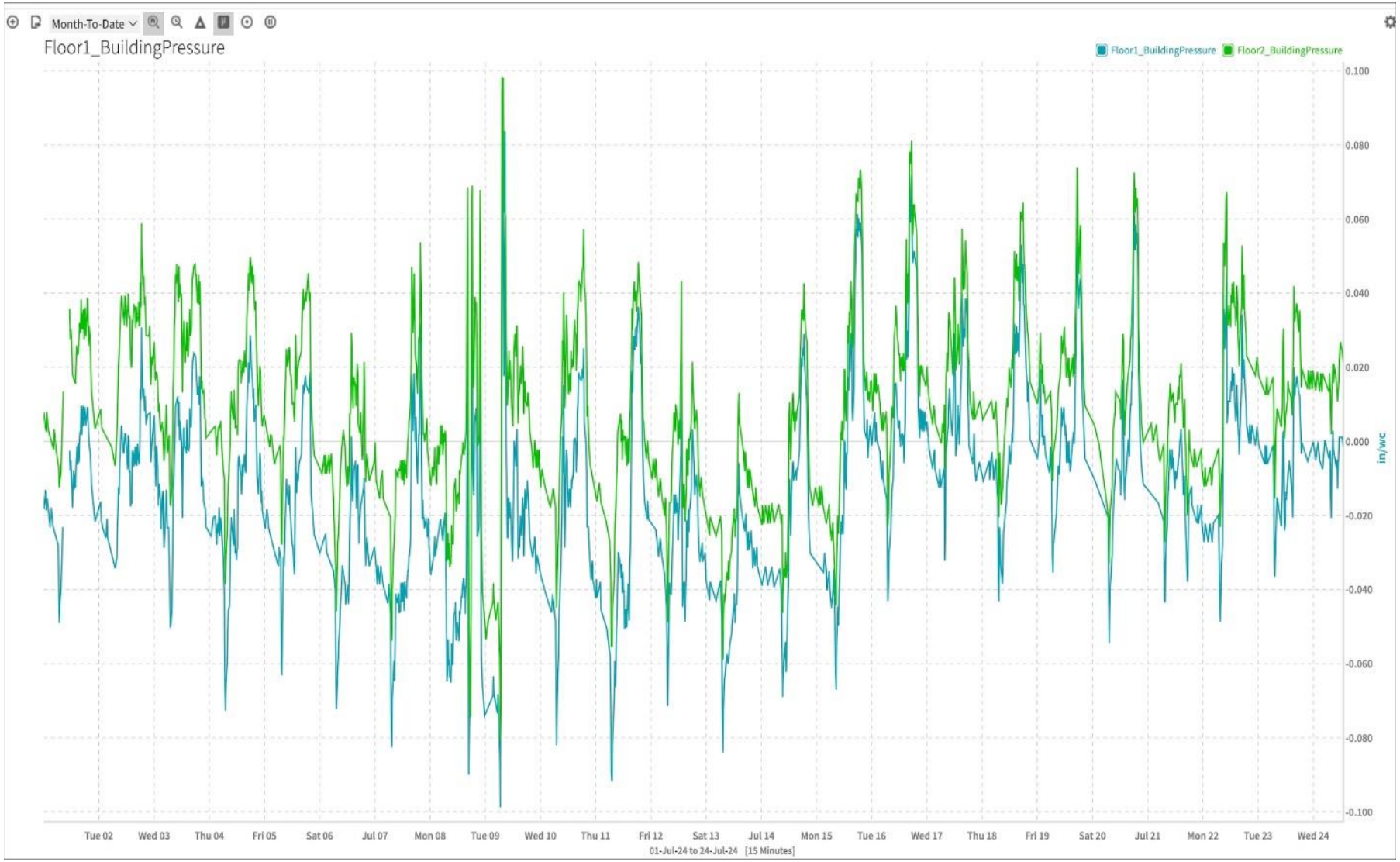
Floor by floor variations in measured building air pressures with digital manometers



Differences in differential air pressures in red between floors at critical periods during a typical day



Extensive cycling of air pressure on floors during typical day



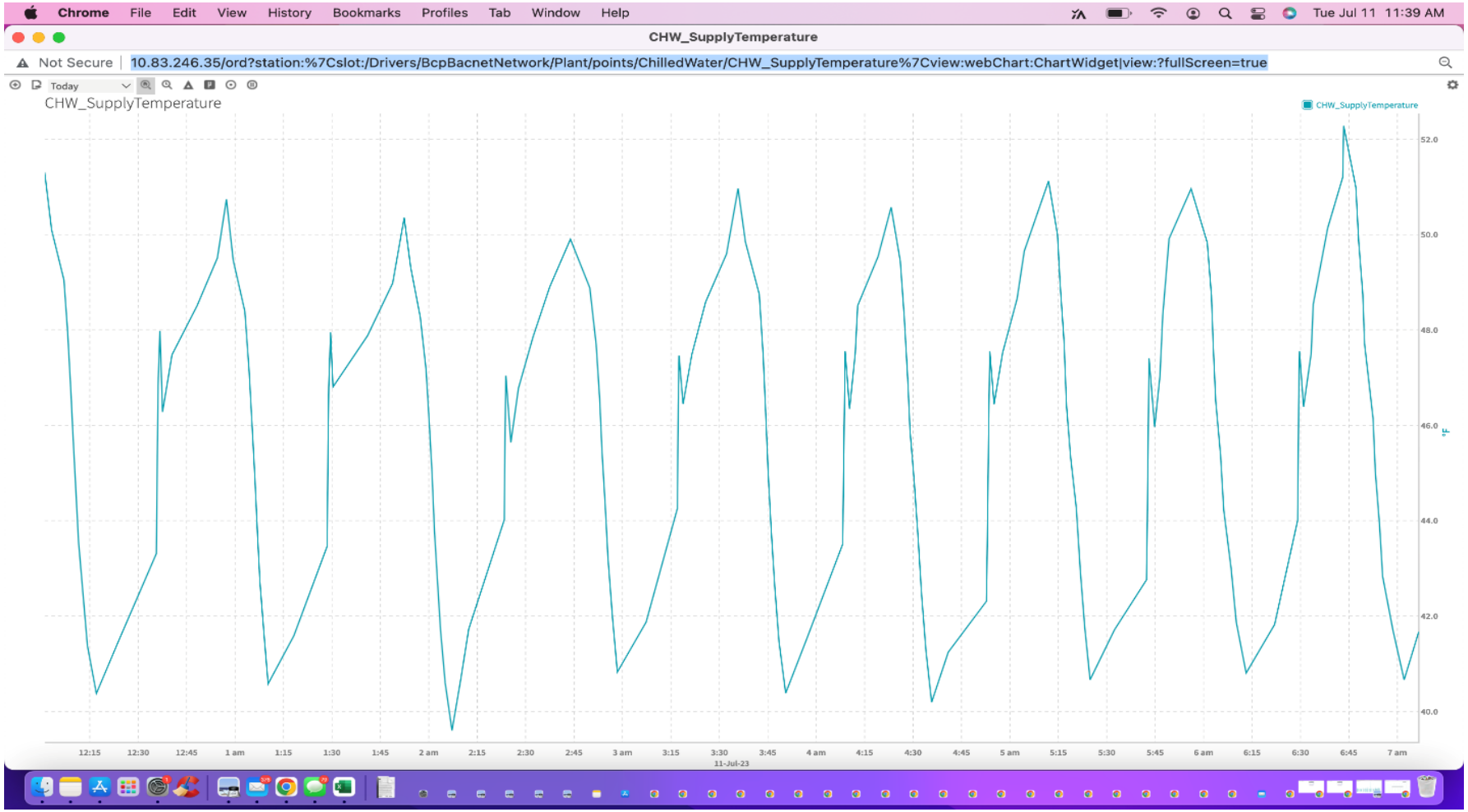
Findings, Resolutions, Verification

Issue	Findings	Resolution
Fluctuation in exhaust hood air valve flow control in Histology	Laminar flow diffuser above hood observed to affect pressure sensor of hood	Added sheet metal shroud above pressure sensor

Findings, Resolutions, Verification

Issue	Findings	Resolution
Inconsistent air handling unit supply air temperatures	Seized chilled water valve Widely fluctuating air handling unit supply air temperature	Repaired and calibrated chilled water valve Water chiller controls recalibrated

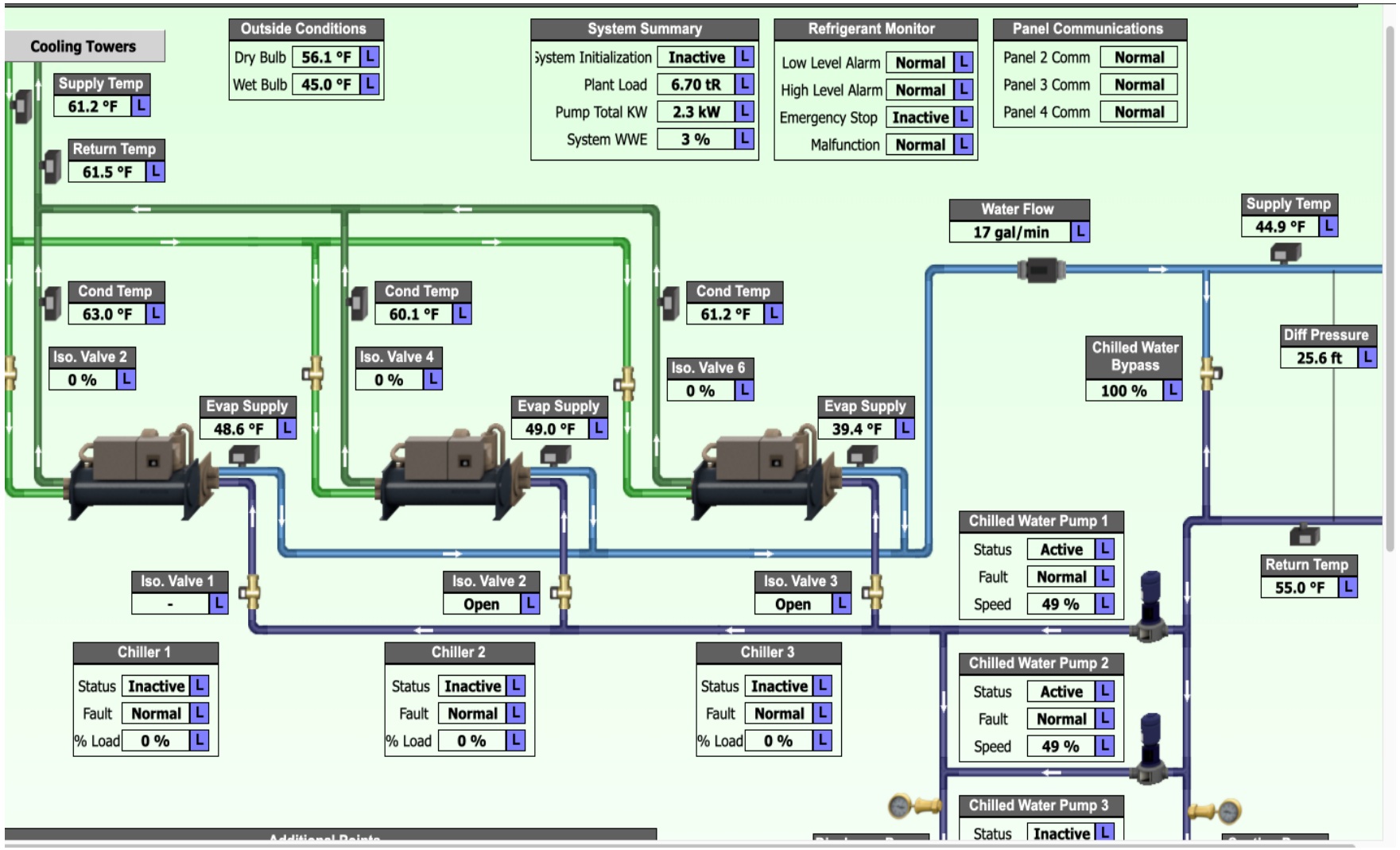
Widely varying air handing unit supply air temperatures



Findings, Resolutions, Verification

Issue	Findings	Resolution
Chillers not loading properly, cycling second chiller on/off every 15-min, cycling off after 15-min	Excessive scale on turbine/impeller type flow meter Meter reading inaccuracies causing problems with chiller staging	Removing, cleaning, and calibrating flowmeter

Chiller schematic with chillers inactive at 56.1˚F outside air temperature and two chilled water pumps operating



Findings, Resolutions, Verification

Issue	Findings	Resolution
VAV terminal boxes containing heating hot water coils Numerous valves either leaking through to coil even when closed and/or leaking down on occupied space/ceiling tile below	Poorly manufactured valves. Closed hot water valves leaking by to coils resulting in VAV box dampers distributing more cooling air flow to spaces to overcome heat gains at heating coils Resulted in high differential pressures of spaces relative to morgue and to outdoors AHUs fans running near full capacity to meet air flow requirements	Replaced and calibrated approximately 100 hot water valves

Findings, Resolutions, Verification

Issue	Findings	Resolution
Locker room exhaust VAV terminal box found open 100%, loss of control signal	Extreme negative pressure in locker room with exhaust fan operating and duct damper 100% open	Restored control signal and calibrated VAV terminal box controls

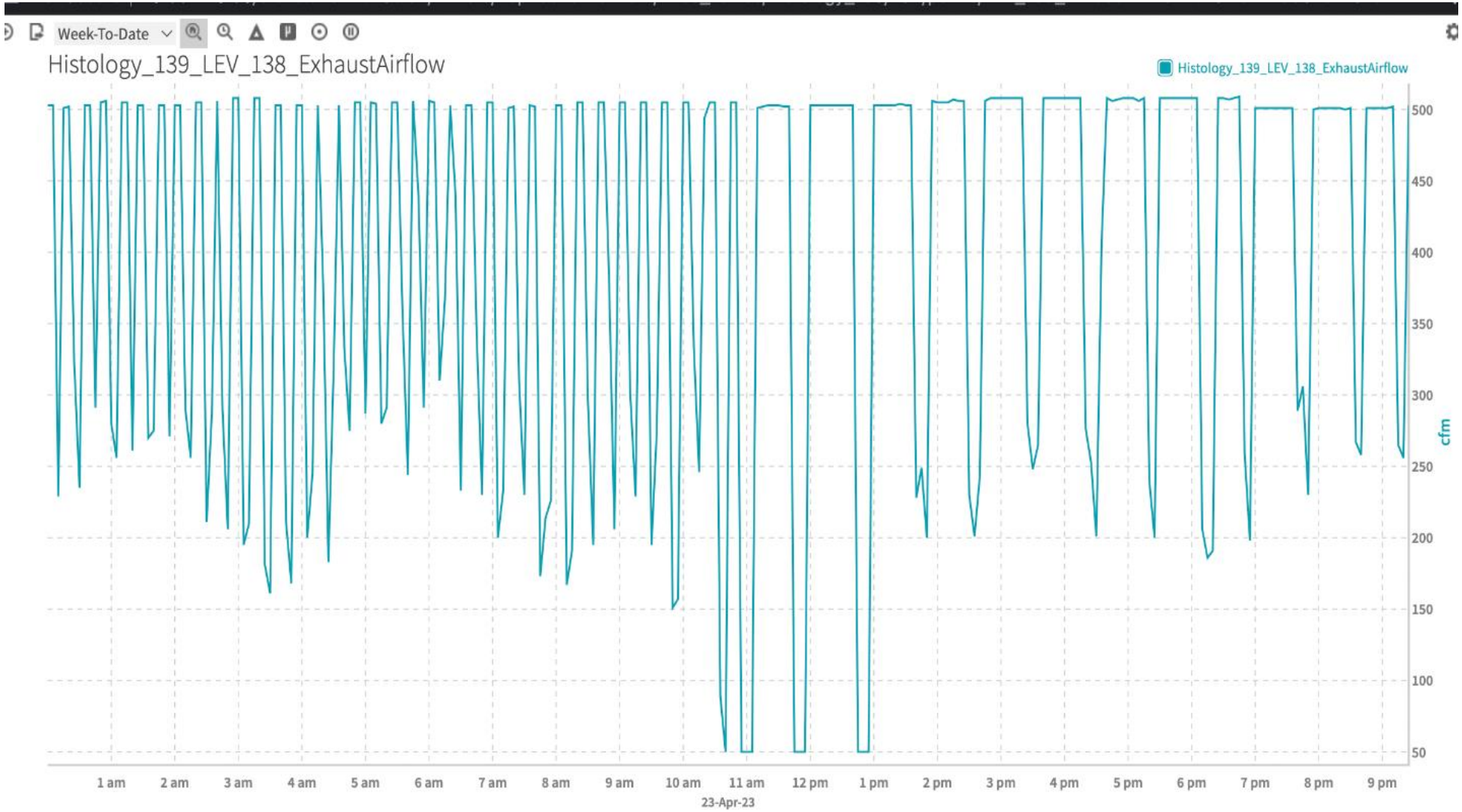
Findings, Resolutions, Verification

Issue	Findings	Resolution
Relief air fan operating without system in economizer mode	High building air pressure on 2nd floor triggering fan to operate	Setpoints adjusted, higher threshold set prior to starting relief air fan 1st and 2nd floor building air pressures balanced to reflect original design Opening of closed fire/smoke damper on return air of 2nd floor lowered 2nd floor building pressure

Findings, Resolutions, Verification

Issue	Findings	Resolution
Pressure in-balance between 1st and 2nd floor admin areas and Morgue	2nd floor more positive than 1st floor relative to Morgue Fire/smoke damper on 2nd floor main return air duct found closed No balancing dampers on two return air openings on first floor Exhaust fan staging (4 total fans, 2 run during unoccupied periods, 3 during typical Morgue occupancy) – pressure spikes during periods when a fan is disabled, pressure dips into negative ranges when a new fan is cycled on at beginning of day	Opened fire/smoke damper. Properly secured damper that was previously unsecured. Added balancing dampers and reduced return air flow from 2nd floor.

Variations in exhaust air flow during typical day



Variations in supply air flow to room 139 during typical day

Findings, Resolutions, Verification

Issue	Findings	Resolution
Helicopter diesel engine fumes from neighboring test facility detected inside building	Under certain wind conditions helicopter engine exhaust fumes found distributed throughout the building Assumed intake through outside air intake	Carbon filters retrofitted to existing AHUs similar to those used near helipads in hospitals

Findings, Resolutions, Verification

Issue	Findings	Resolution
Autopsy room differential pressures relative to adjacent space fluctuated between occupied hours with higher exhaust flow requirements and lower exhaust flows when generally unoccupied	One actuator on supply air valve found faulty and was replaced.	Calibrated VAV terminal box supply air valves supplying autopsy room

Wide variations in autopsy room indoor air pressures

Findings, Resolutions, Verification

Issue	Findings	Resolution
Condensation on ceiling air grilles in intake and release spaces that have doors that open directly to exterior **Procurement area similarly found with condensation on ceiling air grilles**	Space temperature setpoints in these spaces were 65degF - 75degF recommended Rooms are effectively vestibules into the morgue with two sets of sliding doors Doors reportedly designed to prevent opening of either set of doors while the other is open, but were not observed to operate as designed Procurement area found to have failed temperature sensor Condensation corresponded to time when chilled water supply temperatures found cycling between 38degF and 52degF. Dehumidification at AHUs found compromised by high CHWS temps	Room temperature setpoints raised Procurement area temperature sensor replaced Chilled water supply temps and AHU supply air temps levels to more consistent levels by repairing chiller controls

Findings, Resolutions, Verification

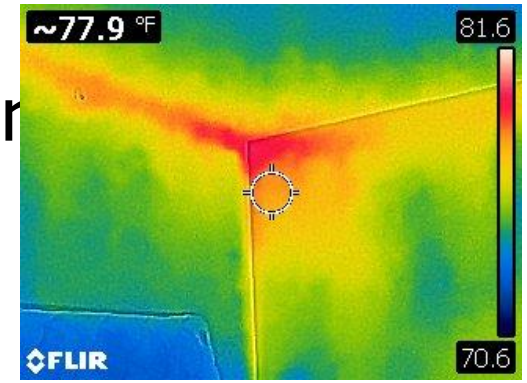
Issue	Findings	Resolution
Exhaust system static pressure setpoint too high	Setpoint originally 1.2-in.w.g, but set to 1.5-in.w.g by facilities maintenance possibly due to Histology alarms or failure of locker room exhaust VAV terminal box that impacted downstream exhaust flowrates	Reset to 1.2-in.w.g following repair of locker room VAV terminal box Building pressure spikes dampened

RBECx/Cx Case History Extended Stay Hotel

- Extended Stay Hotel in Orlando, Florida.
  - Hot, humid climate
- Approx. 1-years old, 6-story 122 guestrooms.
- Terracon performed extensive investigation and testing of the Building Enclosure systems and HVAC:
  - Guestrooms designed to be under negative pressure
  - Incorrect design of parapet wall passive vents
  - Uncontrolled water vapor due to exterior wall insulation substitution
  - Extensive defects in roof and exterior routes of moisture intrusion
  - Retained water in hollow core floor panels from construction increase latent load.

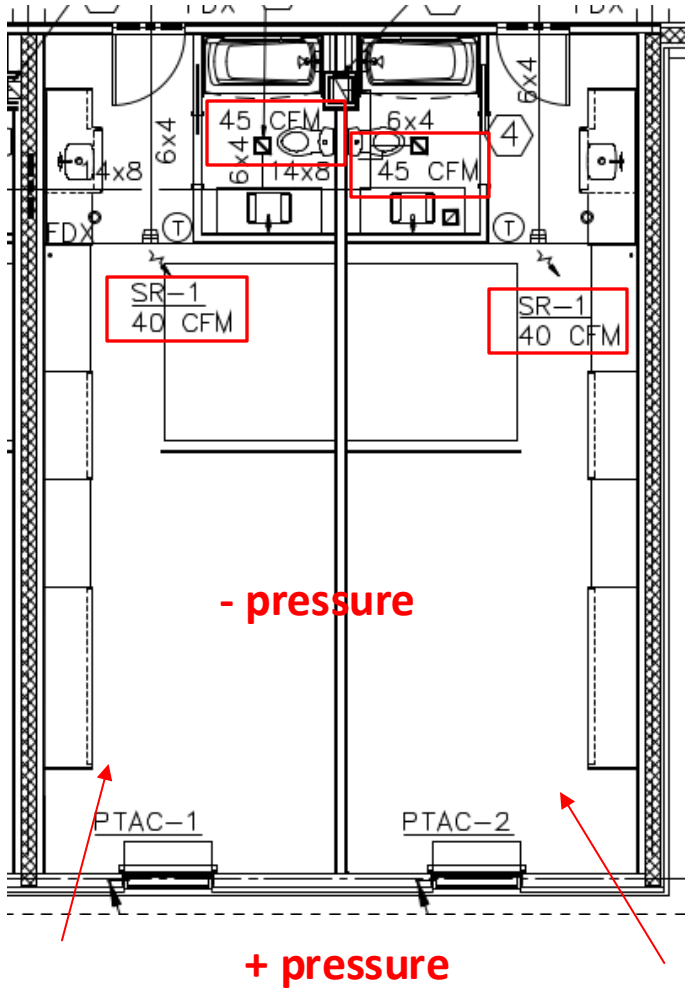
Diagnostics Performed in Investigative Phase

- IR/moisture meter dew point surveys of interior of exterior walls, roof and hollow core floor panels
- Smoke testing of wall cavities
- Test cuts in roof and walls assemblies to confirm construction/pathways
- Sealant testing

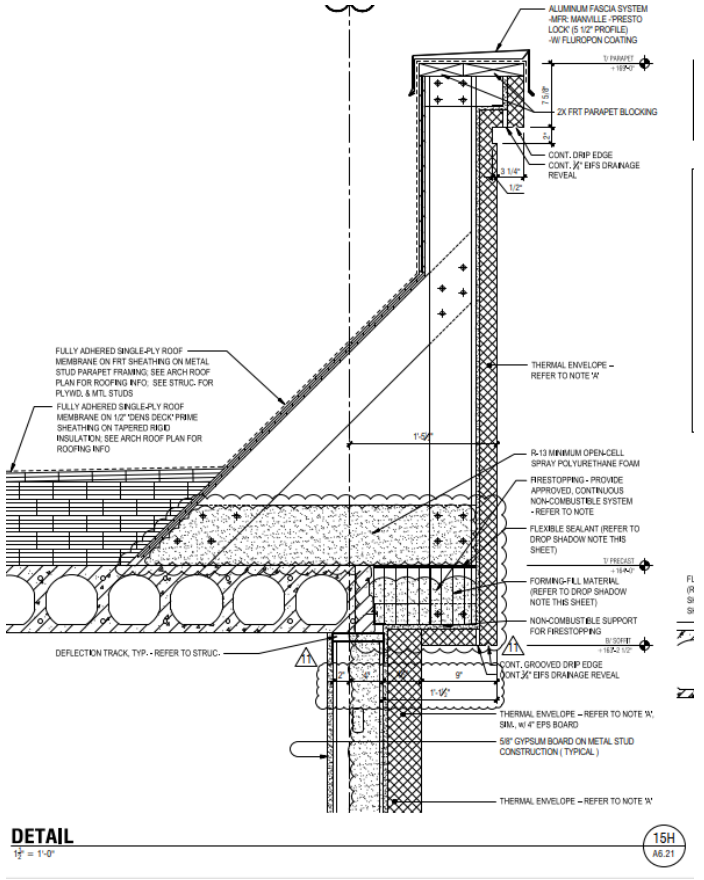


Implementation Phase Activities

- Removed parapet vents, installed missing firestopping
- Sealed openings in rooftop goosenecks
- Repaired roof membrane, replaced failed sealants, recoated EIFS exterior
- Removed/replaced impacted drywall
- Drained water from hollow core panels
- Fixed DOAS units, waterproofed rooftop HVAC
- Retro-commissioned HVAC flows to make rooms positive pressure



Implementation Phase Activities



Verification Phase Activities

- Test and Balance to reset Outdoor Air Flows and bathroom exhaust flows to achieve positive pressure

MUA-1 discharge air temperatures 54.8° db / 52.8° wb. MUA-2 discharge air temperatures 64.2° db / 62.0° wb.

Room #	Pressure	Room #	Pressure
603	+0.003"	619	+0.004"
604	+0.002"	621	+0.003"
503	+0.003"	517	+0.005"
504	+0.004"	521	+0.002"
403	+0.004"	420	+0.001"
406	+0.001"	424	+0.001"
301	+0.001"	323	+0.004"
305	+0.001"	319	+0.002"

Orlando Test & Balance, Inc. — GRILLE DATA SHEET

Testing, Adjusting and Balancing Air Conditioning, Ventilating and Heating Systems — PHONE 877-675-3582

JOB NAME: Home 2 Suites American Way Retro-Commissioning DATE: June 8, 2023

UNIT NUMBER: Outside Air AREA SERVED: As Listed

AREA SERVED		GRILLE #	GRILLE SIZE	GRILLE CODE	K FACTOR	REQUIRED FPM	REQUIRED CFM	PRELIM. FPM	PRELIM. CFM	FINAL FPM	FINAL CFM	% OF DESIGN
Room	601	1	6" x 4"	SR-1	1.0	--	45	--	40	--	42	93%
Room	603	2	6" x 4"	SR-1	1.0	--	45	--	41	--	48	107%
Room	604	3	6" x 4"	SR-1	1.0	--	45	--	42	--	46	102%
Room	605	4	6" x 4"	SR-1	1.0	--	45	--	39	--	45	100%
Room	606	5	6" x 4"	SR-1	1.0	--	45	--	40	--	42	93%
Room	607	6	6" x 4"	SR-1	1.0	--	45	--	43	--	45	100%
Room	608	7	6" x 4"	SR-1	1.0	--	45	--	42	--	45	100%

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JOB NAME: Home 2 Suites American Way Retro-Commissioning DATE: June 8, 2023

UNIT NUMBER: Exhaust AREA SERVED: As Listed

AREA SERVED		GRILLE #	GRILLE SIZE	GRILLE CODE	K FACTOR	REQUIRED FPM	REQUIRED CFM	PRELIM. FPM	PRELIM. CFM	FINAL FPM	FINAL CFM	% OF DESIGN
Room	601	1	6" x 6"	ER-1	1.0	--	35	--	46	--	35	100%
Room	603	2	6" x 6"	ER-1	1.0	--	35	--	45	--	35	100%
Room	604	3	6" x 6"	ER-1	1.0	--	35	--	45	--	35	100%
Room	605	4	6" x 6"	ER-1	1.0	--	35	--	43	--	36	103%
Room	606	5	6" x 6"	ER-1	1.0	--	35	--	42	--	35	100%
Room	607	6	6" x 6"	ER-1	1.0	--	35	--	47	--	33	94%
Room	608	7	6" x 6"	ER-1	1.0	--	35	--	41	--	34	97%
Room	609	8	6" x 6"	ER-1	1.0	--	35	--	42	--	36	103%

Thank you for your time!

Questions and Discussion

Contacts

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